FOREIGN TECHNOLOGY DIVISION
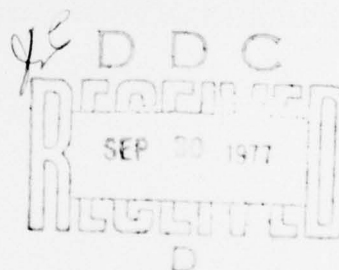
PHOTOPRODUCTION OF Be^7 FROM CARBON,
BORON, BERILLIUM, AND LITHIUM

by

V. I. Noga, Yu. M. Ranyuk, et al.

EDITED TRANSLATION

FTD-ID(RS)I-0407-77   5 April 1977

FTD-77-C-000325

PHOTOPRODUCTION OF Be⁷ FROM CARBON, BORON, BERILLIUM, AND LITHIUM

By: V. I. Noga, Yu. M. Ranyuk, et al.

English pages: 8

Translated by: LINGUISTICS SYSTEMS, INC
         F33657-76-D-0389
         R. Hantula
Requester: FTD/ETDP
Approved for public release; distribution unlimited.

"PHOTOPRODUCTION OF Be^7 FROM CARBON,
BORON, BERILLIUM, AND LITHIUM"

V. I. Noga, Yu. M. Ranyuk, P. V.
et al.

The study of the photoproduction of Be^7 from light nuclei is interesting from the point of view of obtaining information on the mechanism of interaction of high-energy gamma quanta with atomic nuclei. Be^7 is a convenient residual nucleus for the study of nuclear reactions through activation methods. A great number of works now exist in which there is studied the production of the residual nucleus Be^7 under exposure to high--energy protons.

The photoyield of Be^7 was studied in works /1-8/ for $E_{\gamma max}$ = 60 Mev. An exception is the measurements of the yield of Be^7 from carbon /1,2/ that were carried out for a maximal bremsstrahlung of up to 1,000 Mev.

In the present work there are measured the yields of Be^7 from natural isotopic mixtures of the nuclei of carbon, boron, berillium, and lithium in the range of energy $E_{\gamma max}$ from 80 to 1,180 Mev.

Procedure

The decay of Be^7 was identified from the half-life T and energy ε of photons formed in the decay of Be^7 as diagrammed in Figure 1 /9/.

A characteristic feature of the reactions studied is a relatively low induced activity per unit of radiation passing through the target. This is connected with the small magnitude of the cross section, the long half-life of the nucleus Be^7, and the small probability of the transition into a state with energy of 479Mev of Li^7. To shorten the time of radiation the targets were gathered in piles, which were irradiated by electron beams of linear accelerators at 360Mev. and 2 Bev. at the Kharkov Physico-Technical Institute of the Academy of Sciences of the Ukrainian SSR /10/. The characteristics of the targets are given in the table.

Element	Physical State	Mechanical Form	Thickness of Target, g./cm.
Li	Metal	Pressed in container	0.534
Be	Metal	Plate	0.545
B	Powder	Pressed in container	0.685
C	Graphite	Plate	0.43

To avoid oxidation the metal lithium was pressed into aluminum hermetic containers with a diameter of 30 mm. and a thickness of walls of ~0.1 mm. Measurements showed that the activity induced in the container could be ignored. The boron targets were prepared by pressing the powder-like boron into the same containers. All the targets had a natural isotopic make-up.

The yield of Be^7 was measured with respect to the reaction $Al^{27} \rightarrow Na^{24}$. Unfortunately, the yields of this reaction which are measured in various works /11-15/ differ substantially. As a result of supplementary measurements we carried out of the yield of the reaction $C^{12} \rightarrow C^{11}$ /15/ for $E_{\gamma max}$ = 150 Mev., pre-ference was given to the results of Meyer et al. /13/ and Massalke /12/ (see Figure 2).

The procedure of irradiating the targets was as follows. An electron beam was directed at a tantalum radiator with a thickness of 0.1 radiation units. Directly behind the radiator there was placed a pile of targets. In such an arrangement of the experiment, unlike work with a beam of bremsstrahlung, the time of exposure in the irradiation of the targets is practically not affected by the energy of the electrons. A short-coming of the method is the necessity of corrective separation of the contributions of electro- and photoactivation.
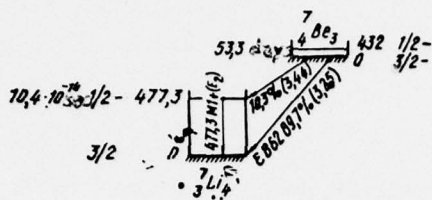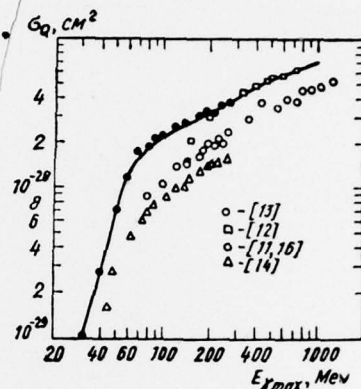
Figure 1. The decay of Be^7 /10/.

Figure 2. The dependence of the yield of the reaction $Al^{27} \rightarrow Na^{24}$ on the maximal bremsstrahlung energy.

When electrons pass through matter there arises bremsstrahlung, whose intensity is proportional to the length of the braking distance passed through by the electrons. It is not difficult to see that the yield of the nuclear reaction for one electron and nucleus-target has the form

$$Y(E_c, t) = \sigma_e(E_0) + \sigma_Q(E_0)t = \sigma_Q(t + t_{equiv}). \qquad (1)$$

Here σ_e is the cross-section of electroactivation, σ_Q is the cross-section of photoactivation for one equivalent photon, t is the braking distance in radiation units, $t_{equiv} = \frac{\sigma_e}{\sigma_Q}$ is the equivalent radiation thickness, which is taken as equal to 0.025 in accordance with the findings of work /10/.

Relationship (1) is valid for values of t that are small by comparison with the radiation unit.

The time of exposure for a stream of electrons onto the converter of ~1 microampere was 2 hours for Li, B, and C and 20 minutes for Be. The berillium targets were irradiated

seperately from the others to avoid the activation of the tar-
gets by photoneutrons. The decay of the residual nucleus Be^7
was registered by a scintillation spectrometer with an NaJ(Tl)
crystal with dimensions of 60×60 cm. /9/ connected with an
AI-128-1 amplitude analyzer. The NaJ crystal with a photomul-
tiplier was located in a protective lead casing with walls 5 cm.
thick.

Measurements were performed two months after irradiation.
With the aid of a Ge(Li)-detector there were made control tests
suggesting that the contribution of annihilation γ-quanta was
practically absent.

Calculation of the reaction cross-sections was performed
by the method of minimal structure /16/. The computations were
done on an M-220 electronic computer.

Results and Discussion

$C^{12} \rightarrow Be^7$. The reaction of photoproduction of Be^7 from
carbon was proposed by Napoli /2/ as a monitor reaction for high
energy photons. The absolute cross-section obtained in this
study equals (0.12 ± 0.02) millibarn and is constant in the
400-900 Mev. photon energy range.

From Figure 3 it is apparent that the cross-sections ob-
tained by us within the limits of error agree with the results
of measurements by other authors /2-5,7,8,17/. The absolute
cross-section $\sigma_K = (0.13 \pm 0.03)$ millibarn for $E_{thresh} = 26.3$
Mev. (the heat of the reaction $C^{12}(\gamma,\alpha n)Be^7$). The yield curve
corresponding to this cross-section and depicted in Figure 3 by
the broken line agrees within the limits of error with the ex-
perimental points, except for energies $E_\gamma \geqslant 1,000$ Mev, where there
is observed a tendency of the cross-section to increase.

$B \rightarrow Be^7$. The yield of Be^7 from borium for one nucleus of

4

the target is shown in Figure 3. The absolute cross-section $\sigma_K = (0.06 \pm 0.02)$ millibarn for $E_{thresh.} = 20$ Mev.
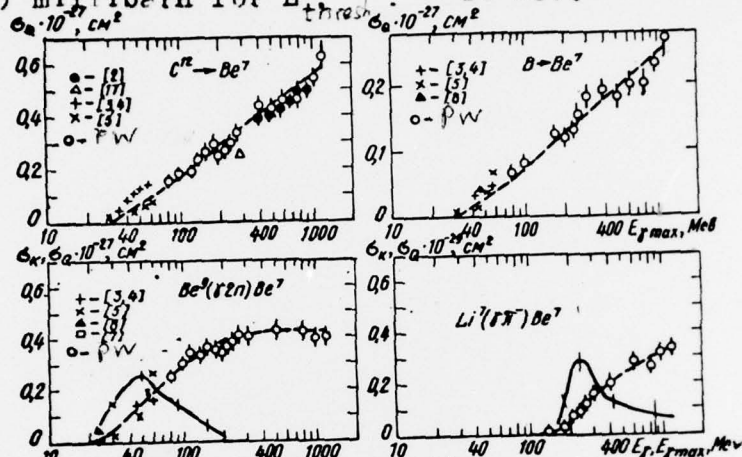

P W = present work

Figure 3. Energy dependency of cross-sections and yields of reactions: $\bigcirc$ - experimental relationship of yield to $E_{\gamma max}$; unbroken curve - σ_k - excitation function, calculated by the method of least squares from experimental data; broken curve - σ_Q - yield corresponding to the excitation function.

$\underline{Be^9 \rightarrow Be^7}$. The heat of reaction Q = -20.6 Mev.

The cross-section of photogeneration of two neutrons on berillium in the region of "giant resonance" was not measured because it is difficult to recreate the excitation function for this reaction. In Figure 3 the broken curve shows the machine approximation of the yield $\sigma_Q(E_{\gamma max})$, the solid curve is the calculated value of $\sigma_k(E_\gamma)$.

From the diagram it is apparent that the form of the cross-section curve is close to the curve for the relation of the full cross-section of deuteron photodisintegration to the energy of the photons, which fact, in our opinion, argues for a quasi-deuteron mechanism for the reaction $Be^9(\gamma 2n)Be^7$.

The fact that the cross-sections of photoproduction of Be^7 from carbon and boron are independent of the energy of the photons, suggests that in those reactions for $E_\gamma > 150$ Mev. an

essential role is played by the processes of photoproduction of π-mesons within the nucleus.

$\underline{Li^7 \rightarrow Be^7}$. The relation of the reaction yield to the maximal energy of the braking spectrum is shown in Figure 4. It is apparent that there is taking place the yield of Be^7 below the threshold of photoproduction of π-mesons, which is due to the photoproduction of Be^7 in impurities and the reaction $Li^7(pn)Be^7$ on secondary protons. We considered the energy dependence of the yields of the reactions that are responsible for the production of Be^7 in the pre-threshold region to be the same as for the reaction $C^{12} \rightarrow Be^7$. The normalized for pre-threshold activity yield of this reaction is shown in the figure by a broken line. The yield after elimination of the background and the excitation function of the reaction are shown in Figure 3. The excitation function was approximated by a fifth order polynomial.

The reaction $Li^7(\gamma\pi^-)Be^7$ is very convenient for theoretical interpretation since in the Be^7 nucleus there are only two bound levels. No one, however, has yet calculated the cross-section of this reaction. It can be estimated with respect to the cross-section of a known reaction, for example, $B^{11}(\gamma\pi^-)C^{11}$, as was done by Meyer and others, from the relationship

$$\frac{\sigma[Li^7(\gamma\pi^-)Be^7]}{\sigma[B^{11}(\gamma\pi^-)C^{11}]} = \frac{N_n(Li^7)}{N_n(B^{11})} \frac{N_K(Be^7)}{N_K(C^{11})} . \qquad (2)$$

where N_n and N_K are the numbers of initial and final states. As was shown in work /18/, $N_n(B^{11})=4$; $N_K(C^{11})=15$.

In the initial state of the Li^7 nucleus there take part in photoproduction two neutrons with the configuration $1P\frac{3}{2}$. The Be^7 nucleus has two levels, including the basic state of nucleons stable for emission with the configuration $1P\frac{3}{2}$, which gives four final states for Be^7. Substituting these values in (2), we obtain

$$\frac{\sigma\left[Li^7\left(\gamma\pi^-\right)Be^7\right]}{\sigma\left[B^{11}\left(\gamma\pi^-\right)C^{11}\right]} = 0,20. \qquad (3)$$

There was experimentally obtained the value 0.3 ± 0.1.
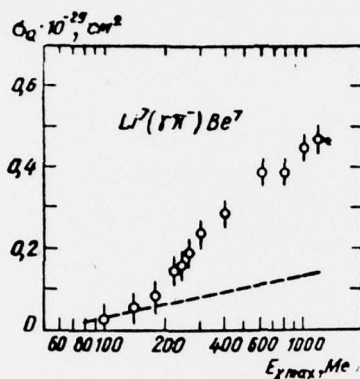

Figure 4. The relationship of the yield of Be[7] from Li[7] to $E_{\gamma max}$: the broken line is the background activity.

Bibliography

1. V. di Napoli et al., Nuovo Cim., 55B, 95, 1968.
2. V. di Napoli, Nucl. Instr. and Method., 69, 155, 1969.
3. H. Artus, G. Fricke, D. E. Von Stein, Zs. Phys., 178, 109, 1964.
4. H. Artus. Zs. Phys., 189, 355, 1966.
5. Y. Oka, T. Kato, A. Yamadera, Bull. chem. soc. Japan, 42, 981, 1969.
6. K. H. Lokan, Proc. Phys. Soc. Lond., A70, 836, 1957.
7. M. S. Foster, A. E. Voight, J. Inorg. Nucl. Chem., 24, 343, 1962.
8. O. L. Garson, G. G. Rocco, J. Inorg. Nucl. Chem., 29, 1, 1967.
9. В. И. Нога, Ю. Н. Ранюк, П. В. Сорокин, УФЖ, 13, № 12, 1968.
10. Б. С. Джелепов, Л. К. Пекер. Схемы распада радиоактивных ядер, М., Изд-во АН СССР, стор. 196.
11. Ю. П. Антуфьев, И. И. Мирошниченко, В. И. Нога, П. В. Сорокин, ЯФ, 6, 431, 1967.
12. A. Massaike, J. Phys. Soc. Japan, 19, No 4, 427, 1969.
13. R. A. Meyer, W. B. Walters, S. P. Hummel, Nucl. Phys., A122, 606, 1968.
14. А. Н. Горбунов, Ф. П. Денисов, В. А. Колотухин, ЖЭТФ, 38, 1684, 1960.
15. W. C. Barber, W. P. George, P. P. Reagan, Phys. Rev., 98, 73, 1955.
16. B. C. Cook, Nucl. Instr and Method., 24, 256, 1963.
17. G. Moscati, B. M. K. Nefkens, J. Todoroff, Bull. Am. Phys. Soc., 9, 407; 1964.
18. R. A. Meyer, W. B. Walters, S. P. Hummel, Phys. Rev., 138, 6B, 1421, 1963.
19. P. Dyal, S. P. Hummel, Phys Rev., 127, 2217, 1967.

Translation of Cyrillic entries:

9. V.I. Noha, Yu.N. Ranyuk, P.V. Sorokin, UFZh, 13, no.12, 1968.

10. B.S. Dzhelepov, L.K. Peker, Schemes of decay of radioactive nuclei, Moscow, ANUSSH, p.196.

11. Yu.P. Antuf'ev, I.I. Miroshnichenko, V.I. Noga, P.V. Sorokin, YaF, 6,431, 1967.

14. A.N. Gorbunov, F.P. Denisov, V.A. Kolotukhin, ZhETF, 38,

1084, 1960.

Physico-technical Institute
Academy of Sciences Ukrainian SSR
Kharkov

PHOTOPRODUCTION OF Be⁷
FROM CARBON, BORON, BERILLIUM AND LITHIUM

V. I. Noga, Yu. N. Ranyuk, P. V. Sorokin, V. A. Tkachenko

Summary

The nuclide Be⁷ was produced by irradiating carbon, boron, berillium and lithium with bremsstrahlung from the Kharkov electron linear accelerator. Yield curves are measured and cross-sections are calculated for photons up to 1180 MeV.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER FTD-ID(RS)I-0407-77	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PHOTOPRODUCTION OF Be^7 FROM CARBON, BORON, BERILLIUM, AND LITHIUM		5. TYPE OF REPORT & PERIOD COVERED Translation
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) V. I. Noga, Yu. M. Ranyuk, et al.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Foreign Technology Division Air Force Systems Command U. S. Air Force		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 1971
		13. NUMBER OF PAGES 8
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

20

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION		MICROFICHE	ORGANIZATION		MICROFICHE
A205	DMATC	1	E053	AF/INAKA	1
A210	DMAAC	2	E017	AF/ RDXTR-W	1
B344	DIA/RDS-3C	8	E404	AEDC	1
C043	USAMIIA	1	E408	AFWL	1
C509	BALLISTIC RES LABS	1	E410	ADTC	1
C510	AIR MOBILITY R&D LAB/FIO	1	E413	ESD	2
C513	PICATINNY ARSENAL	1		FTD	
C535	AVIATION SYS COMD	1		CCN	1
C557	USAIIC	1		ETID	3
C591	FSTC	5		NIA/PHS	1
C619	MIA REDSTONE	1		NICD	5
D008	NISC	1			
H300	USAICE (USAREUR)	1			
P005	ERDA	2			
P055	CIA/CRS/ADD/SD	1			
NAVORDSTA (50L)		1			
NAVWPNSCEN (Code 121)		1			
NASA/KSI		1			
544 IES/RDPO		1			
AFIT/LD		1			

FTD-ID(RS)I-0407-77